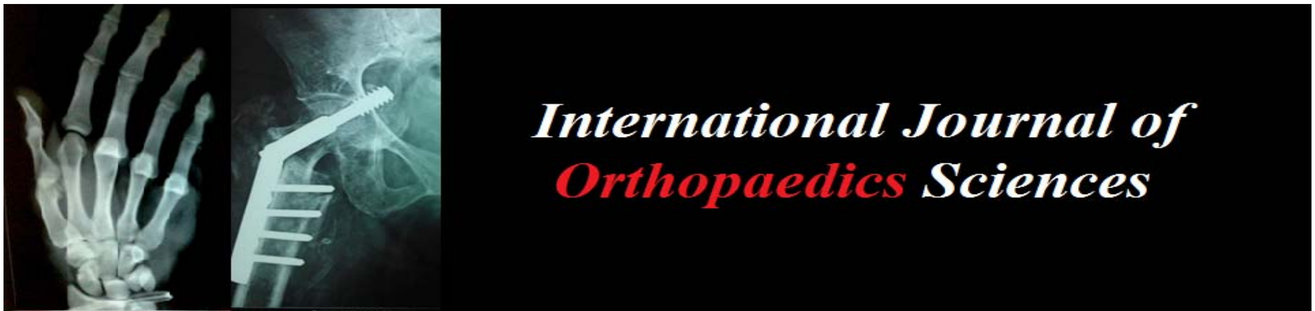



**ISSN:** 2395-1958
IJOS 2017; 3(2): 665-670

www.orthopaper.com
Received: 07-02-2017
Accepted: 08-03-2017

**Dr. Y Bhanu Rekha**
M.S (Ortho), Associate Professor, Department of Orthopaedics, Kamineni Institute of Medical Sciences, Narketpally, Nalgonda (Dist.) Telangana, India

**Dr. V Surya Prakash Rao**
M.S (Ortho), DNB (Ortho) Consultant Spine Surgeon, Maxcure Hospitals, Hyderabad, Telangana, India

**Correspondence**
**Dr. Y Bhanu Rekha**
M.S (Ortho), Associate Professor, Department of Orthopaedics, Kamineni Institute of Medical Sciences, Narketpally, Nalgonda (Dist.) Telangana, India

# Evaluation of pulmonary function in adolescent idiopathic thoracic scoliosis

**Dr. Y Bhanu Rekha and Dr. V Surya Prakash Rao**

**DOI:** http://dx.doi.org/10.22271/ortho.2017.v3.i2g.67

**Abstract**
Pulmonary function is known to be effected adversely in congenital and infantile scoliosis. But the changes in lung function in adolescent scoliosis are not much studied. We evaluated 33 patients with adolescent idiopathic thoracic or thoracolumbar scoliosis with Cobb's angle more than 40º. Spirometry was done for all the patients pre-operatively. Percentage predictions of Total lung capacity, Forced vital capacity and Forced expiratory volume in one second were studied to evaluate pulmonary function. These variations were compared against Cobb's angle, hypokyphosis, number of involved vertebrae and coronal imbalance. We found that only number of involved vertebrae has significant correlation with decreased lung function. Cobb's angle, coronal imbalance and hypokyphosis did not have any significant association to the decreased lung function in our analysis.

**Keywords:** Pulmonary function, adolescent idiopathic scoliosis, thoracic scoliosis

## 1. Introduction
Scoliosis is a three dimensional deformity of the spine in coronal, sagittal and axial planes. Ribs are also distorted secondary to the malformation of thoracic vertebrae. This leads to decrease in thoracic volume, resulting in impairment of pulmonary function in scoliosis.
Lung development proceeds through multiplication and hypertrophy of alveoli. Alveoli multiply at a rapid rate up to the age of four years [1]. Alveolar hypertrophy occurs at a faster rate up to eight years, though it continues until 25 years. So, infantile scoliosis which appears below three years is thought to be severely affected due to decreased number of alveoli, followed by juvenile scoliosis with alveolar hypotrophy. Idiopathic scoliosis is long presumed to have no effect on lung function, since lungs are almost fully developed by the time scoliosis develops [2].
But recent evidence shows that thoracic cage in children with idiopathic scoliosis is narrower than in normal children [3]. This reduced space leads to decreased lung growth, similar to infantile and juvenile scoliosis though to a lesser extent than them. Because of deformity, respiratory muscle mechanics is also shown to be poor in these children [4], which again leads to restrictive lung function
Very few studies of pulmonary function were done in adolescent idiopathic scoliosis. We evaluated lung function in 33 adolescent patients with significant degree of idiopathic thoracic or thoracolumbar scoliosis.

## 2. Materials and methods
33 patients with adolescent idiopathic thoracic and thoracolumbar scoliosis operated between 2001 and 2005 at Nizams Institute of Medical Sciences were evaluated. Congenital, neuromuscular and other forms of scoliotic patients were excluded. Thoracic scoliosis was classified according to Lenke's classification. Out of 33 patients, 14 patients had type 1, two patients had type 2, 13 patients had type 3 and four patients had Lenke type 6 scoliosis. 14 patients were girls and 19 patients were boys. The average age was 17 years.
All patients underwent pulmonary function test with a standard dry rolling seal spirometer (Spiro 232, product code no. 435, manufactured by Morgan Medical Ltd.)
Among the several parameters of pulmonary function, total lung capacity (TLC), forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_1$) were taken into consideration.

TLC and FVC represent lung volumes and $FEV_1$ represents airflow. Instead of absolute values of TLC etc., percentage of values seen in normal children of same age, sex and height were taken into account. The corrected height of the children with scoliosis was calculated from their arm span, according to the formula devised by Kono *et al* [5].

Severe impairment of respiratory function was said to be present if FVC or TLC was less than 50%, moderate impairment if FVC was between 51 and 65%, mild if it was 66-80%. If FVC was more than 80%, it was considered normal. The parameters of scoliosis included the magnitude of scoliosis as measured by Cobb's angle, number of vertebrae involved, kyphosis of the scoliotic segment and coronal imbalance.

After compiling the data, correlation co-efficients were calculated between the parameters of scoliosis and pulmonary function. The parameters which showed significant correlation were entered into regression analysis and their independent predictabilities were measured.

## 3. Results

### 3.1 Forced vital capacity

FVC showed significant inverse correlation with number of vertebrae (r=-0.5, P=0.0033). The degree of scoliosis, kyphosis and coronal imbalance did not have significant association.

On regression analysis, the no. of involved vertebrae was found to be an independent significant predictor of FVC and was responsible for 26.24% of the variability in FVC.

### 3.2 Forced expiratory volume in one second

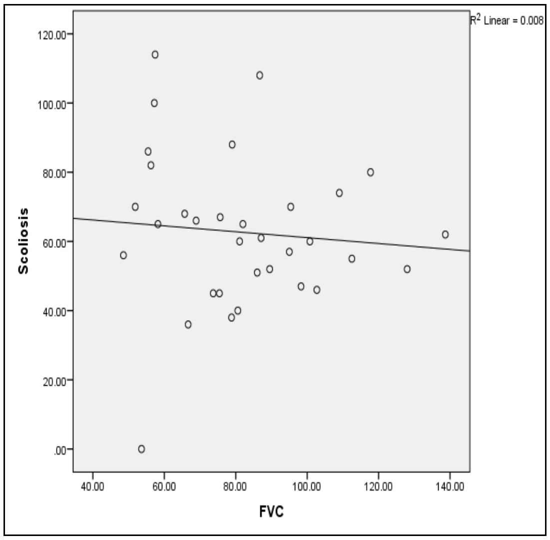
$FEV_1$ showed significant negative correlation with the degree of scoliosis (r=-0.4, P = 0.0197) and with the no. of involved vertebrae (r= - 0.4, P= 0.0183). These two variables were entered into the regression analysis and only no. of vertebrae was found to be significant independent predictor. It caused 19.22% of variability of lung function.

### 3.3 Total lung capacity

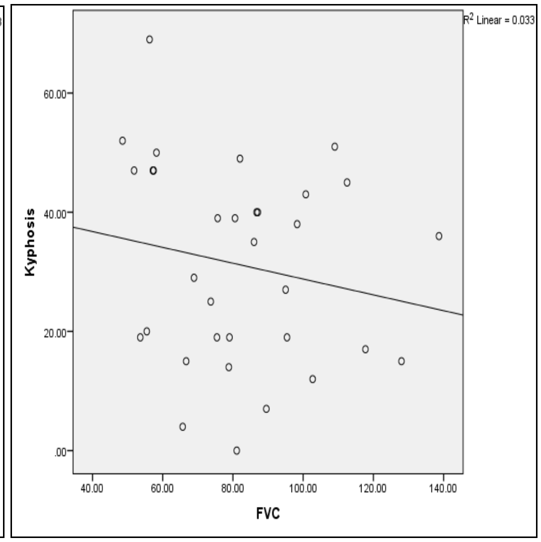
TLC has significant negative correlation with the no. of involved vertebrae. (r= -0.47, P= 0.0054) It was also shown to be an independent significant predictor on regression analysis. 22% of the variability of the TLC was explained by the variations of the no. of involved vertebrae.

**Table 1:** Table showing number of involved vertebrae, apex, scoliosis, kyphosis, coronal imbalance (mm), FVC, $FEV_1$, and TLC of all patients

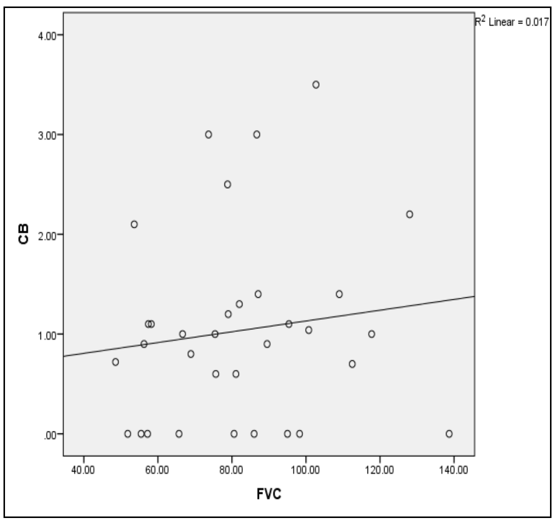
| Name | Type | Number of vertebrae | Apex | Scoliosis | Kyphosis | CB(cm) | FVC(L) | FEV1(L) | TLC(L) |
|---|---|---|---|---|---|---|---|---|---|
| AK | 3 | T4-T11,8 | T8,R | 65° | 50° | 1.1 | 58.21 | 59.68 | 55.99 |
| CH | 3 | T7-L1,5 | T11,L | 40° | 39° | 0 | 80.58 | 87.83 | 73.15 |
| JL | TL | T9-L2, 6 | T12 R | 45° | 19° | 1 | 75.43 | 76.78 | 67.5 |
| LA | 2 | T6-T12,7 | T10R | 46° | 12° | 3.5 | 102.7 | 99.49 | 101.7 |
| LK | 3 | T6-L1,6 | T9-T10,L | 55° | 45° | 0.7 | 112.5 | 100.92 | 115.08 |
| NY | 2 | T5-T12,8 | T10R | 86° | 20° | 0 | 55.46 | 51.4 | 60.33 |
| RK | 3 | T4-T11,8 | T9,R | 60° | 0° | 0.6 | 81.08 | 86.47 | 73.02 |
| SAB | 3 | T5-T10, 6 | T8, L | 67° | 39° | 0.6 | 75.64 | 62.5 | 67.9 |
| SM | 3 | T7-L1, 7 | T11, R | 62° | 36° | 0 | 138.68 | 135.36 | 132.97 |
| SO | 3 | T6-T12,7 | T10R | 45° | 25° | 3 | 73.68 | 76.57 | 65.6 |
| SK | 2 | T7-T12,6 | T1OR | 66° | 29° | 0.8 | 68.9 | 69.27 | 63.85 |
| SU | 2 | T6-T12, 7 | T9 | 68° | 4° | 0 | 65.69 | 69.36 | 57.32 |
| SW | 3 | ,T3-T10,7 | T7 | 57° | 27° | 0 | 95 | 104 | 80 |
| HL | 2 | T5-T10,6 | L,T8 | 47° | 38° | 0 | 98.28 | 95.15 | 92.54 |
| MS | 3 | T4-L1, 10 | T8 R | 82° | 69° | 0.9 | 56.25 | 65.76 | 48.5 |
| NA | 2 | T1-T9, 9 | T5R | 65° | 49° | 1.3 | 82 | 98 | 73 |
| RA | 3 | T4-T9,6 | T6, R | 51° | 35° | 0 | 86 | 84 | 82 |
| RR | 2 | T8-L2,7 | T11,R | 80° | 17° | 1 | 117.74 | 98.41 | 114.21 |
| SMK | 2 | T3-T10,8 | T7R, | 114° | 47° | 1.1 | 57.42 | 53.57 | 56.86 |
| VB | 2 | T7-L1, 7 | T10,R | 60° | 43° | 1.04 | 100.75 | 94.44 | 94.34 |
| VS | 2 | T6-T12, 7 | T9, R | 67° | 19° | 2.1 | 53.61 | 54.83 | 49.21 |
| SA | 2 | T3-T12, 10 | T7,R | 56° | 52° | 0.72 | 48.55 | 61.05 | 39.76 |
| SI | 2 | T5-T128 | T9,R | 70° | 19° | 1.1 | 95.39 | 106.63 | 80.98 |
| SL | 3 | T6-T12,7 | R,T9 | 36° | 15° | 1 | 66.67 | 75 | 56.61 |
| ZJ | 3 | T3-T10,8 | T6,R | 38° | 14° | 2.5 | 78.82 | 75.47 | 76.12 |
| SL | 2 | T4-T9,6 | T7,R | 61° | 40° | 1.4 | 87.09 | 92.52 | 76.44 |
| AR | TL | T10-L1,4 | T12,L | 52° | 15° | 2.2 | 128 | 129 | 123.52 |
| VR | 4 | T8-L2,7 | T11,L | 74° | 51° | 1.4 | 109 | 95.67 | 116.91 |
| SU | 3 | T6-T12,7 | T9,R | 88° | 19° | 1.2 | 79 | 79 | 79 |
| VS | TL | T9-L4, 7 | L1,R | 108° | 40° | 3 | 86.71 | 60.61 | 70.03 |
| VJ | 3 | T2-T11, 10 | T5,R | 100° | 47° | 0 | 57.2 | 58.45 | 54.31 |
| NA | TL | T10-L2, 5 | T7L | 52° | 7° | 0.9 | 89.5 | 90.5 | 78.2 |
| VRR | 2 | T6-T12, 7 | T9, R | 70° | 47° | 0 | 51.85 | 50.51 | 48.02 |
| MEAN | | | | | | | 82 | 82 | 76.5 |



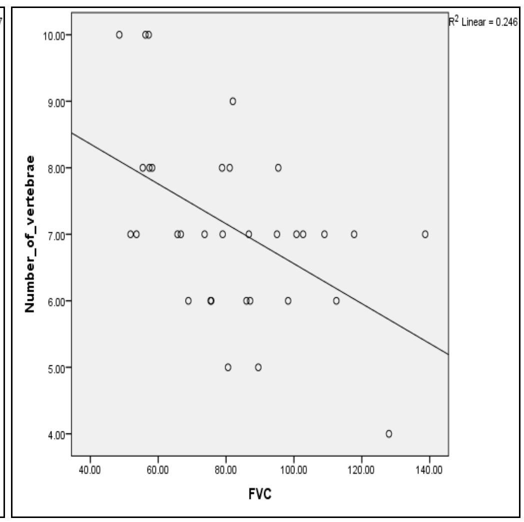

Scatter plot between Cobb's angle and FVC




Scatter plot between kyphosis and FVC

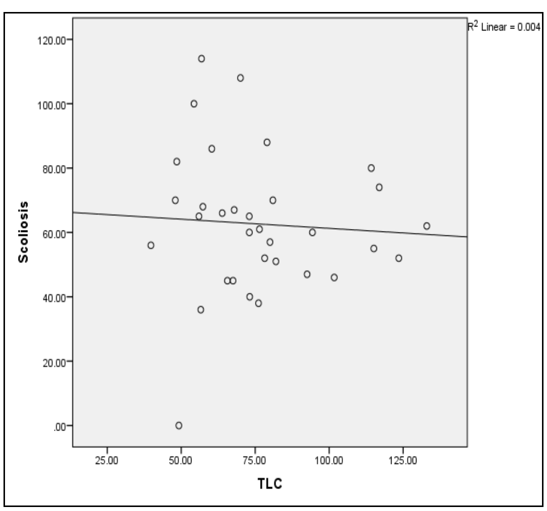



Scatter plot between coronal imbalance and FVC.

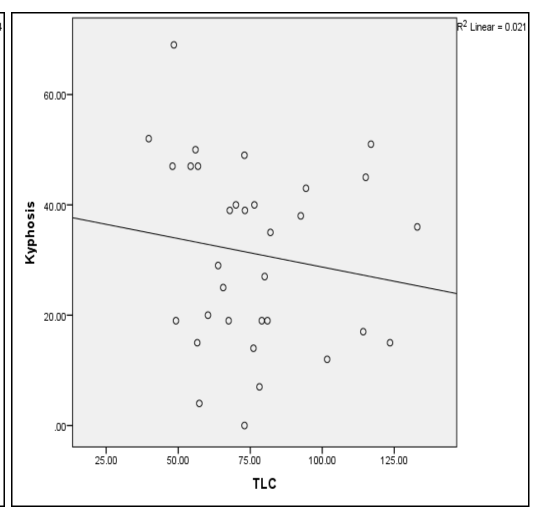



Scatter plot between no.of vertebrae and FVC

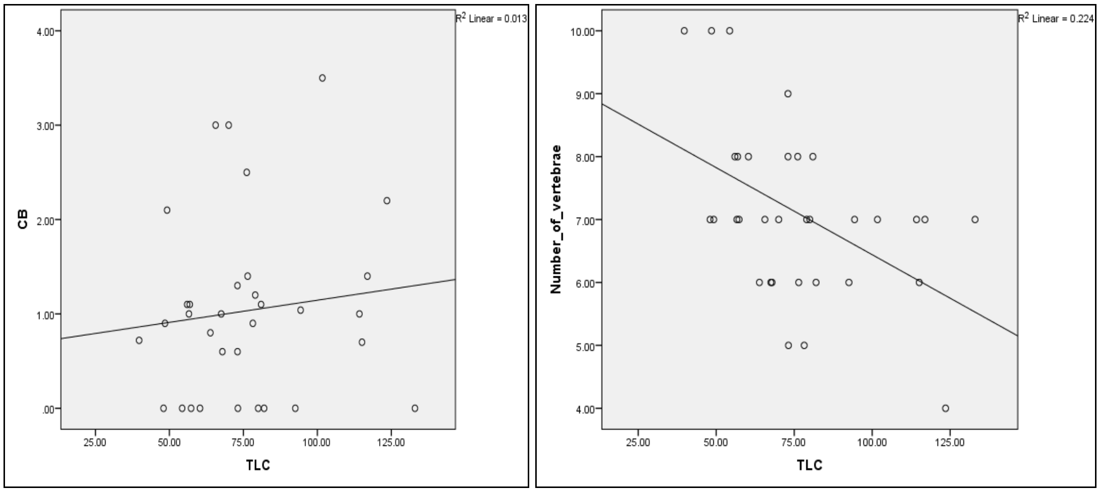
**Fig 1:** showing relation between scoliosis and forced vital capacity




Scatter plot between Cobb's angle and TLC

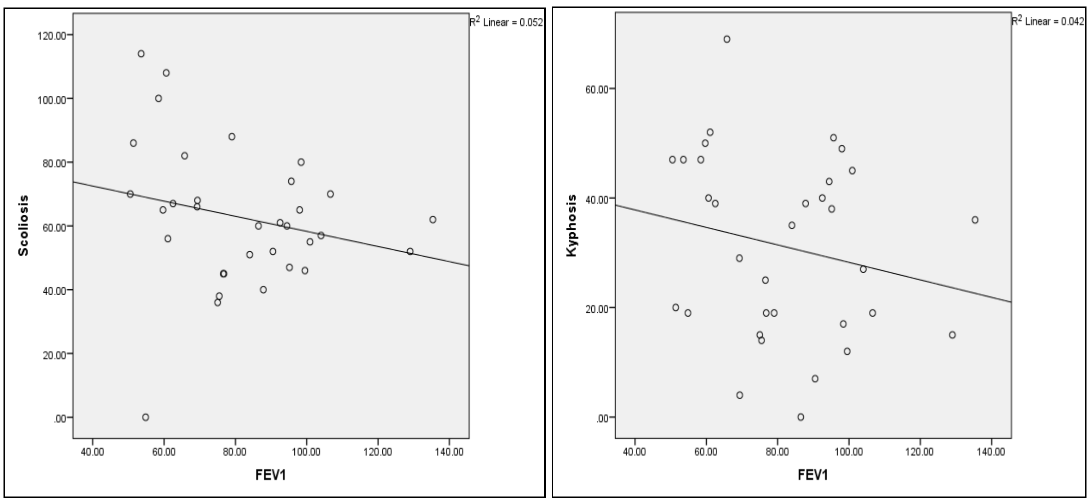



Scatter plot between kyphosis and TLC




Scatter plot between CB and TLC. Scatter plot between no. of vertebrae and TLC

**Fig. 2:** showing relation between scoliosis and total lung capacity.




Scatter plot between Cobb's angle and $FEV_1$ Scatter plot between kyphosis and $FEV_1$

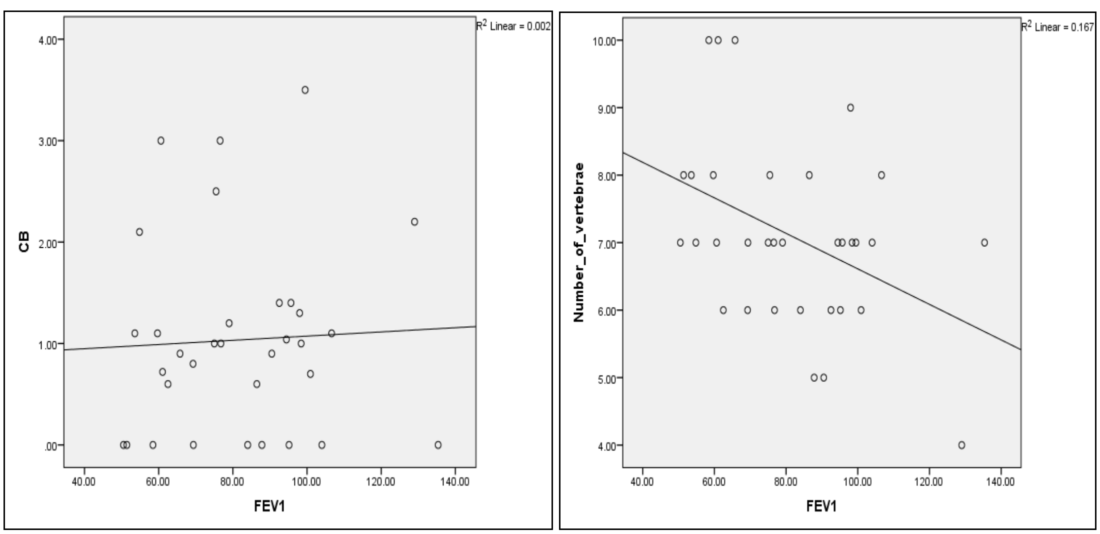



**Fig. 3:** showing relation between scoliosis and forced expiratory volume in one second.

Scatter plot between CB and $FEV_1$

Scatter plot between no. of vertebrae and $FEV_1$

As only the number of involved vertebra was found to be significant, the patients were classified according to it.

- Class a-patients with no. of involved vertebrae <6
- Class b-patients with no. of involved vertebrae-7
- Class c-patients with no. of involved vertebrae-8
- Class d-patients with no. of involved vertebrae-9,10

Lung function was studied in each class separately. Less than 65% of predicted value was taken to be clinically relevant as it significantly influences post-operative ventilatory support
Number of patients in –
Class a – 10
Class b – 13
Class c – 6
Class d – 4

### 3.4 FVC
FVC was sharply affected once the number of involved vertebrae increased to 8. Less than 65% of FVC was seen in 15% of patients in class b, 50% of patients in class c and 75% of children in class d.

### 3.5 TLC
Less than 65% of FVC was seen in 30% of patients in class b, 50% of patients in class c and 75% of children in class d.

### 3.6 $FEV_1$
Less than 65% of $FEV_1$ was seen in 10% of patients in class b, 23% of patients in class c and 50% of children in class d.

**Table 2:** Relation between lung function and number of vertebrae

| | FVC less than 65% | TLC less than 65% | $FEV_1$less than 65% |
|---|---|---|---|
| Class b (n=7) | 15% of class b | 30% of class b | 10% of class b |
| Class c (n=8) | 50% of class c | 50% of class c | 23% of class c |
| Class d (n=9,10) | 75% of class d | 75% of class d | 50% of class d |

n=number of vertebrae in scoliotic curve

## 4. Discussion
A study of pulmonary function test in 38 patients with thoracic and thoracolumbar scoliosis was done by J. Johari *et al* [6]. They tried to correlate the pulmonary function with degree of coronal plane deformity and location of apical vertebra. They could not find any significant correlation between Cobb's angle and pulmonary function, but they found that FVC was higher in patients with lumbar scoliosis than with thoracic scoliosis. In our study, since patients with lumbar scoliosis were excluded, we could not compare pulmonary function between thoracic and lumbar scoliosis. However, this study concurred with our conclusion that lung function cannot be predicted from the severity of coronal plane deformity.
Johnston *et al.* [7] did a clinical study with a multicenter database comprising of 858 patients. They found that pulmonary function decreases if Cobb's angle was more than 80º in thoracic curves or if thoracic kyphosis was less than 10º. In our study, seven patients had scoliotic curves of more than 80º Cobb's angle. These seven patients as a group had much lower average FVC, $FEV_1$ and TLC as compared to the other group of 26 patients. We had six patients with thoracic kyphosis less than 15º, but their FVC, $FEV_1$ and TLC values were indistinguishable from the rest.
Pre-operative pulmonary function testing was done by Newton *et al*. [8] in 631 patients. They found that pulmonary function was impaired with the increasing severity of thoracic curve, number of vertebrae involved, thoracic hypokyphosis and coronal imbalance. In our study, we found that only number of vertebrae involved had significant impact on respiratory function.
According to the study by kearon *et al*. [9] in 66 patients, vital capacity was significantly reduced if more vertebrae were involved, in accordance to our findings. But they also concluded that cobb's angle and hypokyphosis had significant negative influence, which was not seen in our study.
The evaluation of pulmonary function was done by Upadhyay S.S *et al*. [10] in 70 patients with adolescent idiopathic thoracic scoliosis. They found that better pulmonary function was associated with rib-vertebral angle asymmetry of less than 25º, rotational flexibility of more than 55º and kyphosis greater than 15º. They too ascertained that Cobb's angle was not linearly associated with reduced pulmonary function.
Hasan-Allah-Sadeghi *et al*. [11] also showed that the correlation between Cobb's angle and pulmonary function was insignificant, which was similar to our conclusion.
Satoru Demura *et al*. [12] studied lung function in 154 patients pre-operatively and post-operatively. According to them, location of curve in proximal thoracic spine had deleterious effect on pulmonary function. They found negative correlation between magnitude of scoliosis and TLC, FVC and $FEV_1$. Hypokyphosis also had a weak negative effect on $FEV_1$, but no effect in FVC and TLC.
To summarize, pulmonary function is negatively impacted by the degree of scoliosis and hypokyphosis, but linear relationship cannot be consistently shown in all the studies. The effect of number of involved vertebrae on lung function is studied by only a few, but all confirmed that it has a significant negative linear relationship.

## 5. Conclusion
Respiratory function is significantly affected if more than seven vertebrae are involved in adolescent idiopathic thoracic scoliosis. In such situations, thorough evaluation of respiratory function is warranted pre-operatively. The magnitude of Cobb's angle, presence of hypokyphosis and extent of coronal imbalance did not predict lung function in our study.

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